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The Engineering and Technology of Mobile Phone Networks in the UK

Newcomen Society - 9th November 2016

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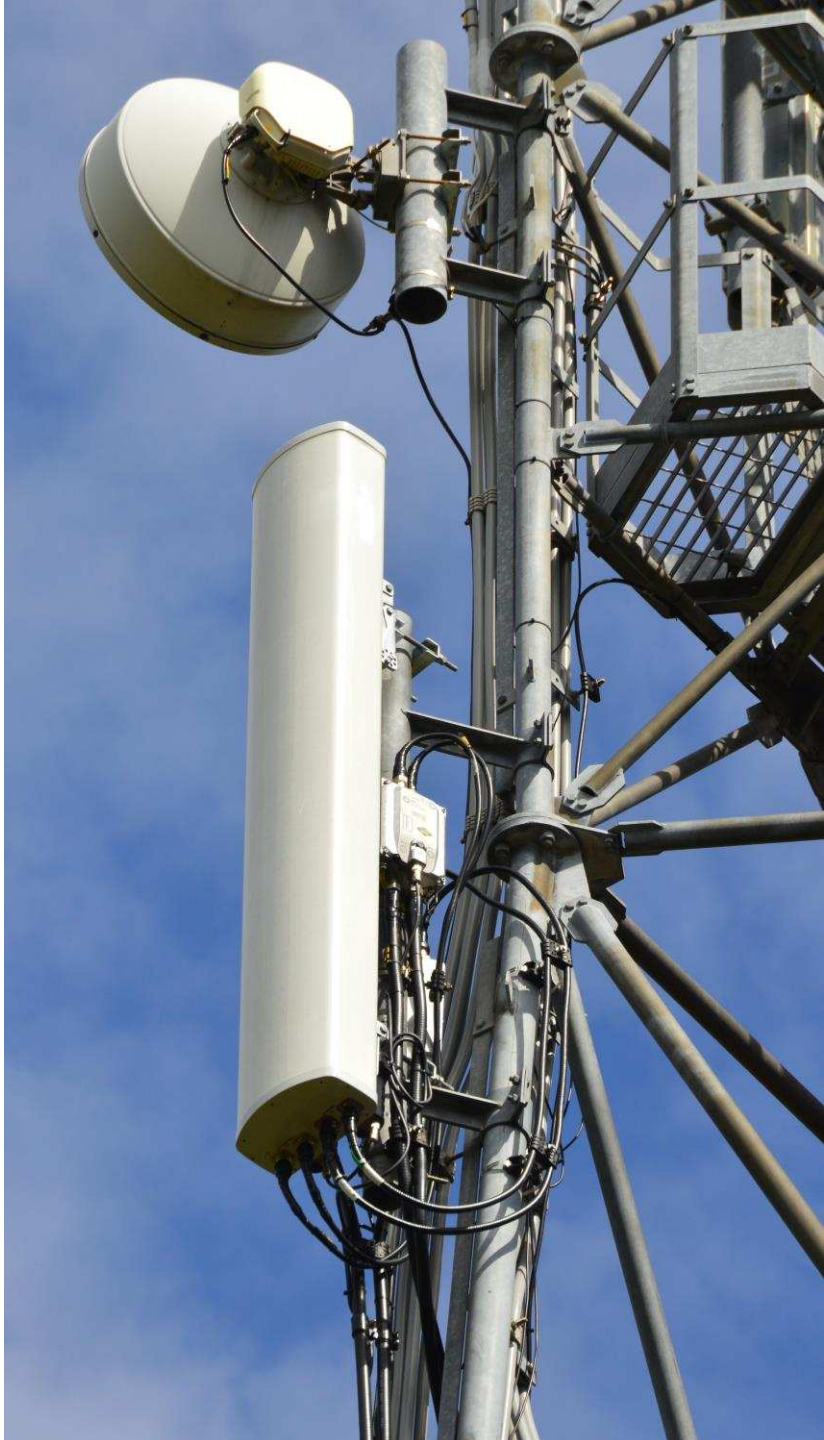
Contents

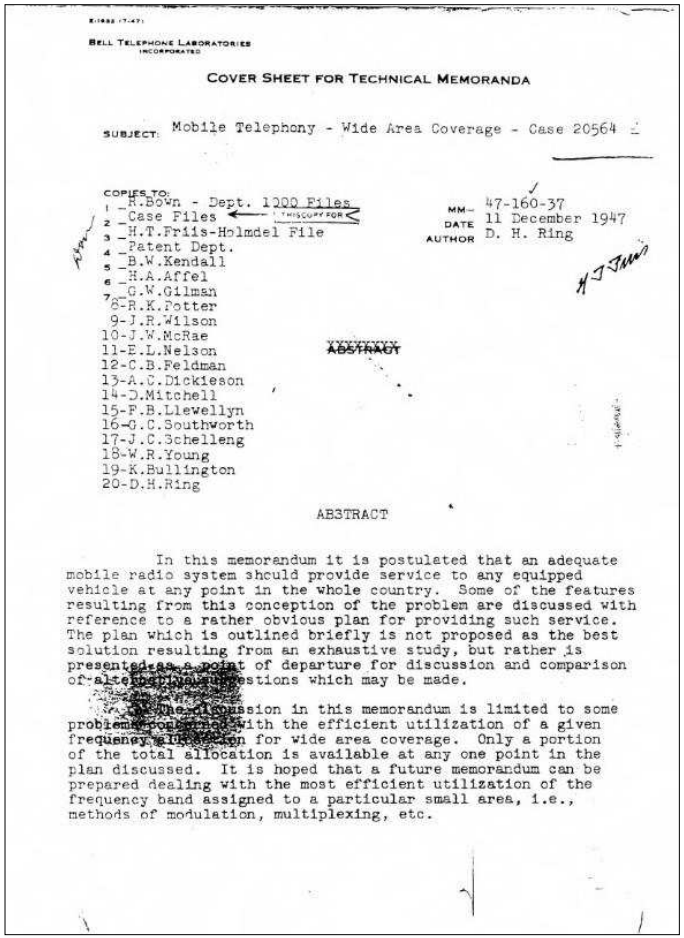


Introduction

- There are more mobile phones in the UK than people
- Mobile subscriptions continue to grow as ever more things are connected to the Internet, via mobile networks
- Today's mobile phone networks are a complex mix of multiple different radio access technologies, backhaul solutions and frequency bands
- GSM/GPRS/EDGE
- UMTS/HSDPA/HSUPA/HSPA/HSPA+
- LTE/LTE-A/LTE-A-P
- …and there's more to come with eLTE and 5G + integration of cellular and WiFi

The invention of cellular

- The cellular principle was proposed in December 1947 by Douglas H. Ring of Bell Telephone Laboratories, USA
- Paper entitled: Mobile Telephony - Wide Area Coverage
- Sets out the basic principles of a cellular network in which the target coverage area is divided up into a series of small geographic areas called cells, each of which is controlled by a single radio base station



BELL TELEPHONE LABORATORIES
INCORPORATED

COVER SHEET FOR TECHNICAL MEMORANDA

SUBJECT: Mobile Telephony - Wide Area Coverage - Case 20564

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13-A.C.Dickieson
14-D.Mitchell
15-F.B.Llewellyn
16-O.C.Southworth
17-J.C.Schelleng
18-W.R.Young
19-K.Bullington
20-D.H.Ring

MM- 47-160-37
DATE 11 December 1947
AUTHOR D. H. Ring

ABSTRACT

ABSTRACT

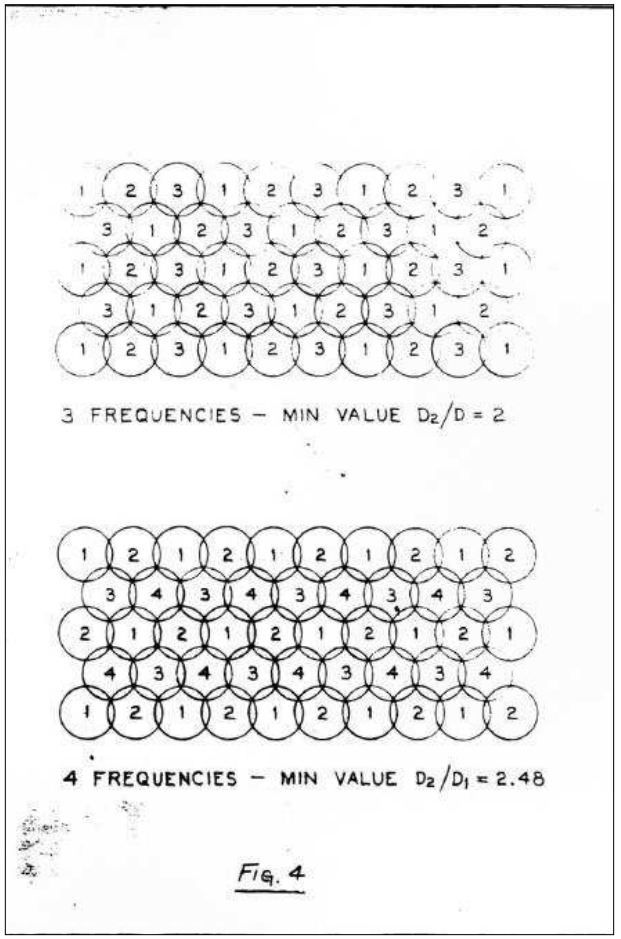
In this memorandum it is postulated that an adequate mobile radio system should provide service to any equipped vehicle at any point in the whole country. Some of the features resulting from this conception of the problem are discussed with reference to a rather obvious plan for providing such service. The plan which is outlined briefly is not proposed as the best solution resulting from an exhaustive study, but rather is presented as a point of departure for discussion and comparison of alternative suggestions which may be made.

The discussion in this memorandum is limited to some problems connected with the efficient utilization of a given frequency allocation for wide area coverage. Only a portion of the total allocation is available at any one point in the plan discussed. It is hoped that a future memorandum can be prepared dealing with the most efficient utilization of the frequency band assigned to a particular small area, i.e., methods of modulation, multiplexing, etc.

The invention of cellular

•By keeping the transmitted power low, a key feature of this architecture was that frequencies could be re-used providing that no two adjacent cells used the same set of frequencies

•Unfortunately for Bell Labs, the technology in 1947 was simply not capable of realising this vision



UK mobile timeline

- 1980s - Government policy of privatisation and introduction of competition to the UK telecoms market
- 1985 - Vodafone launched the UKs first mobile network, followed by Cellnet
- 1993 - Mercury one2one launched the world's first DCS1800 (later known as GSM1800) network, in the UK
- 1994 - Orange launched the UKs 4th mobile network
- 2000 - BT Cellnet launched the world's first GPRS network
- 2000 - BT Cellnet switched off its analogue (TACS/E-TACS) network
- 2001 - Vodafone switched off its analogue (TACS/E-TACS) network
- 2003 - H3G (3) launched the UKs first UMTS (3G) network
- 2006 - Orange launched the UKs first EDGE network
- 2007 - Vodafone launched the UKs first HSDPA network
- 2012 - EE launched the UKs first LTE network
- 2014 - EE launched the UKs first LTE-Advanced network

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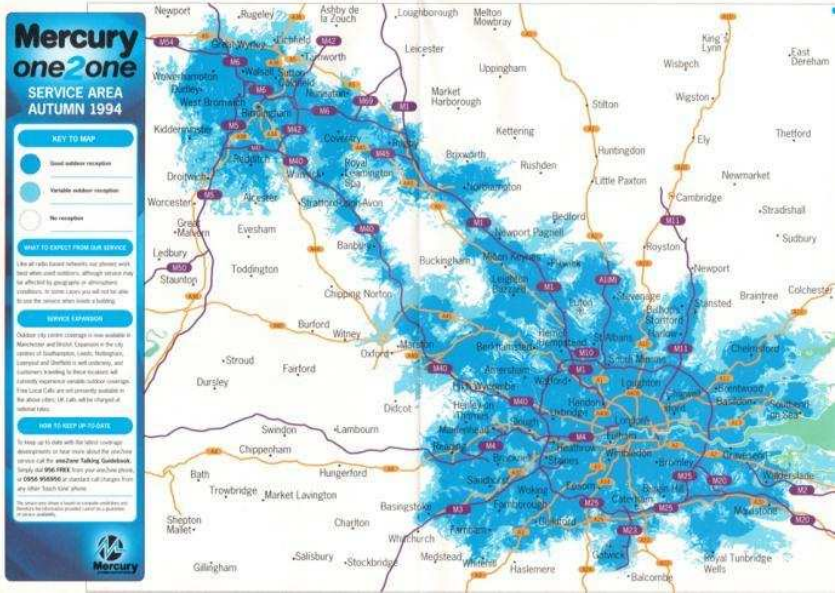
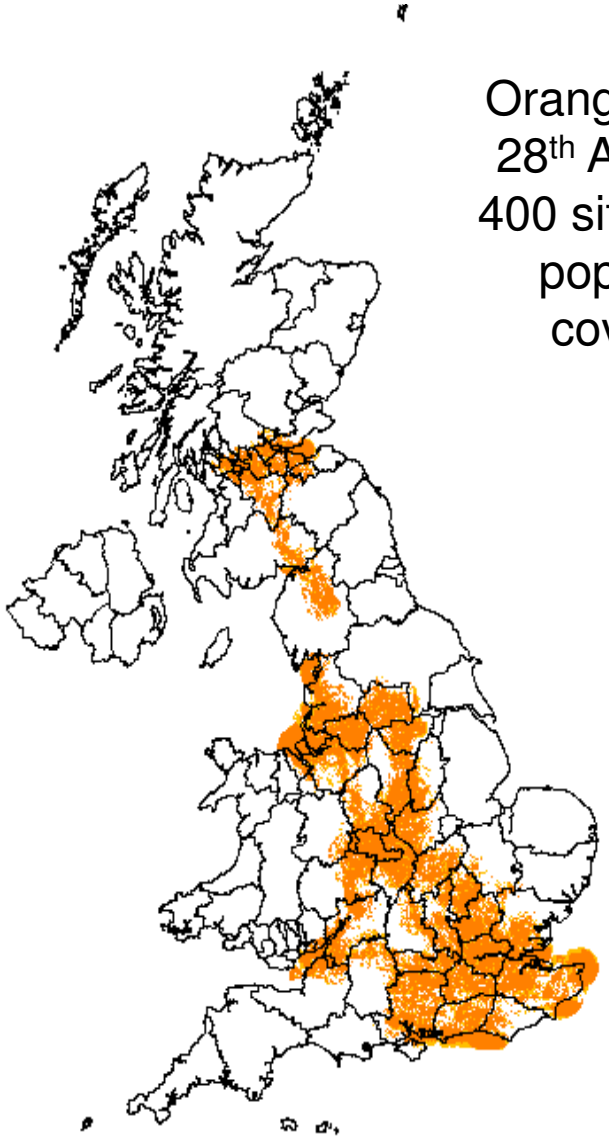
GSM (2G) NETWORK ROLLOUT

Network coverage

•Cellular radio network coverage initially focused on major population centres and communications links (roads and railways)



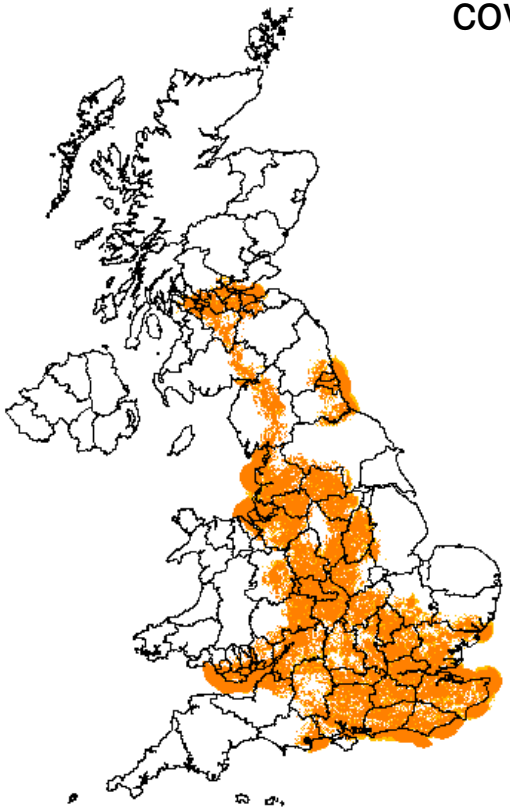
Measurement criteria was somewhat different in 1994! External coverage and car kits….



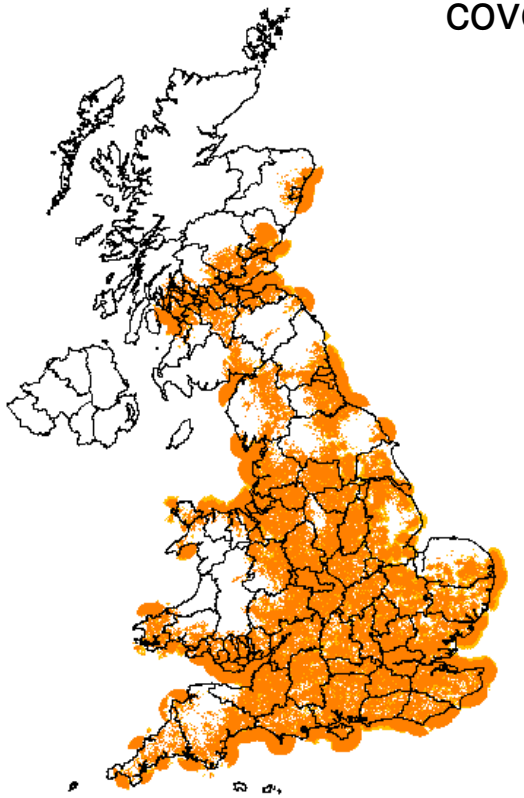
Orange launch:
28th April 1994
400 sites = 50% population coverage

Network coverage

End of 1994
900 sites = 70% population coverage

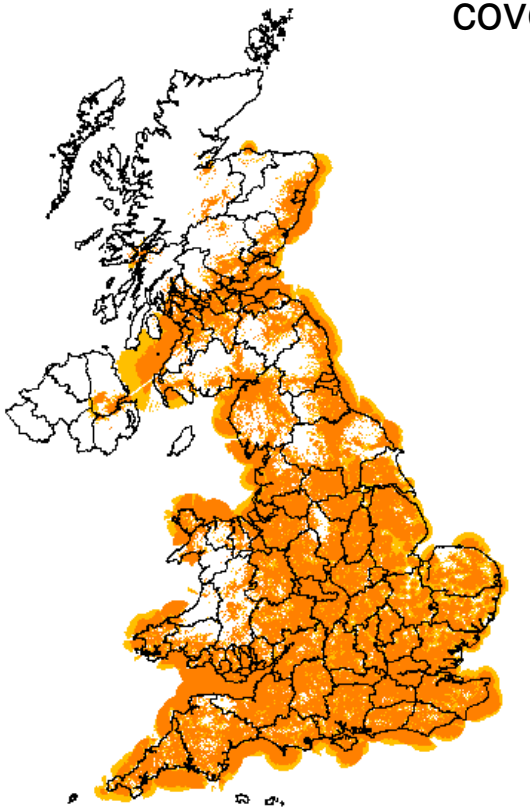


End of 1996
2500 sites = 92% population coverage

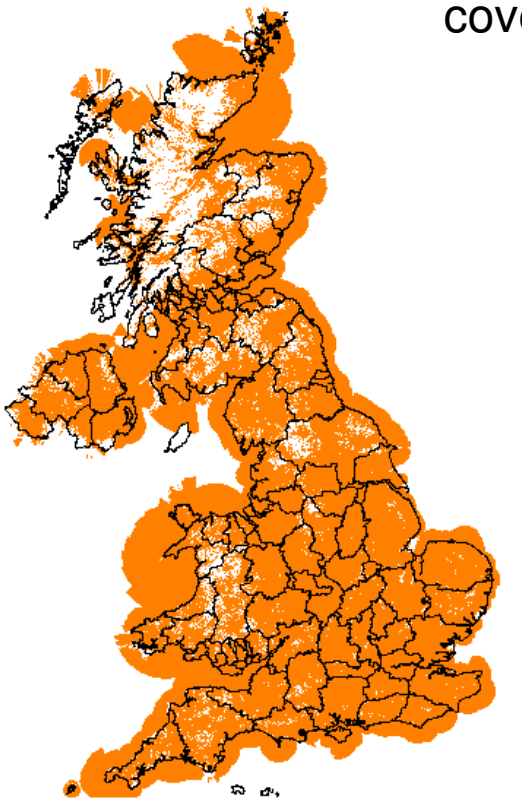


Network coverage

End of 1997
3500 sites =
97% population
coverage

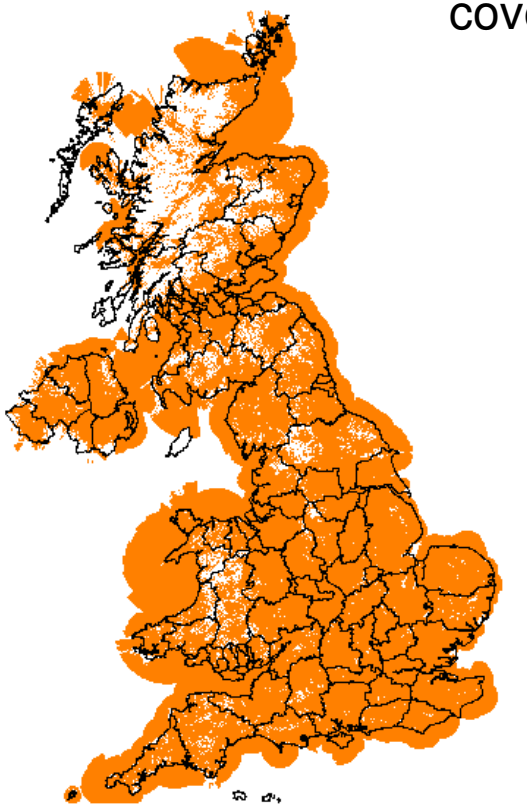


Summer of 1999
6000 sites =
99% population
coverage

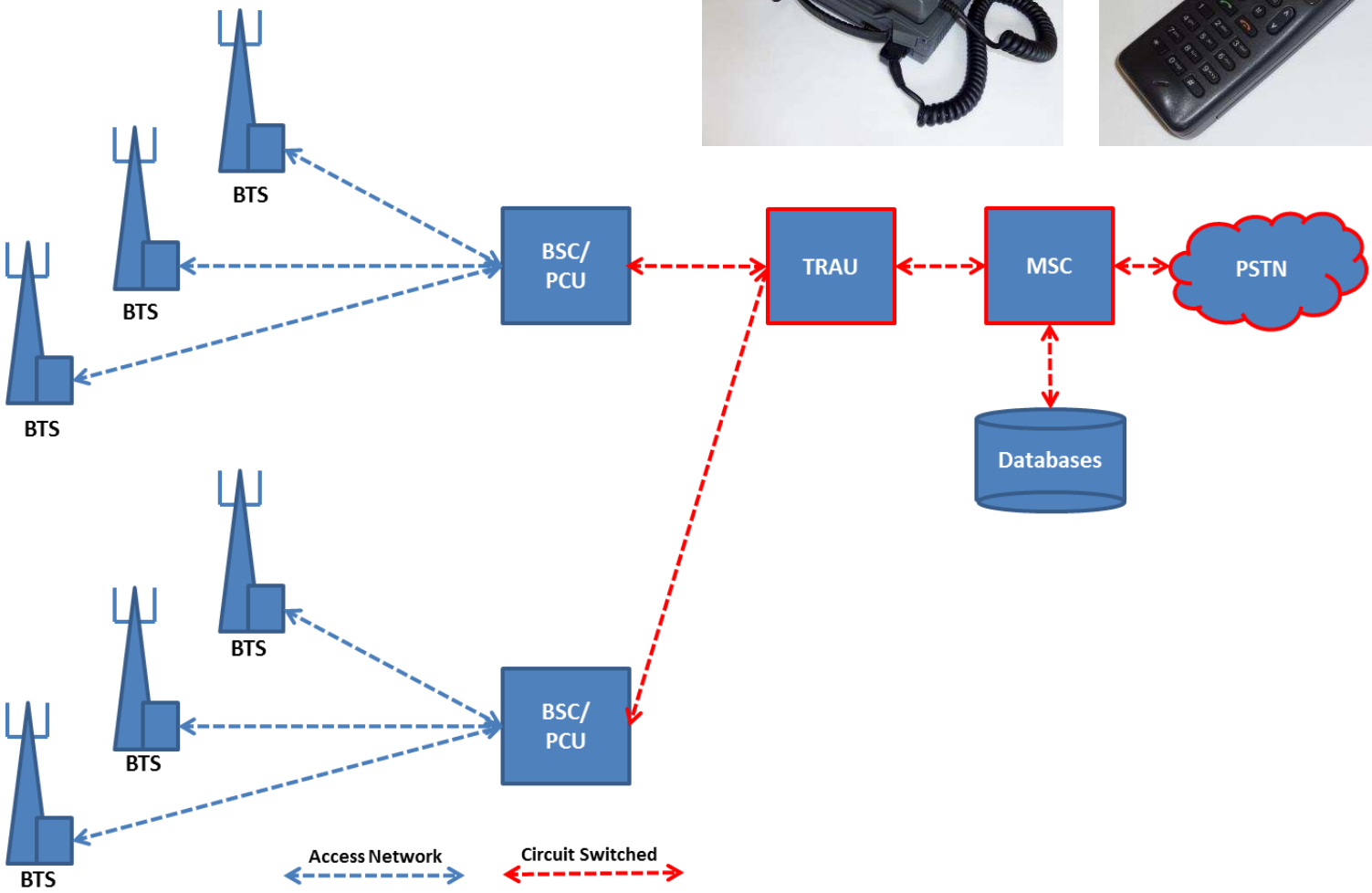


Network coverage

End of 2001
10,000 sites =
>99% population
coverage

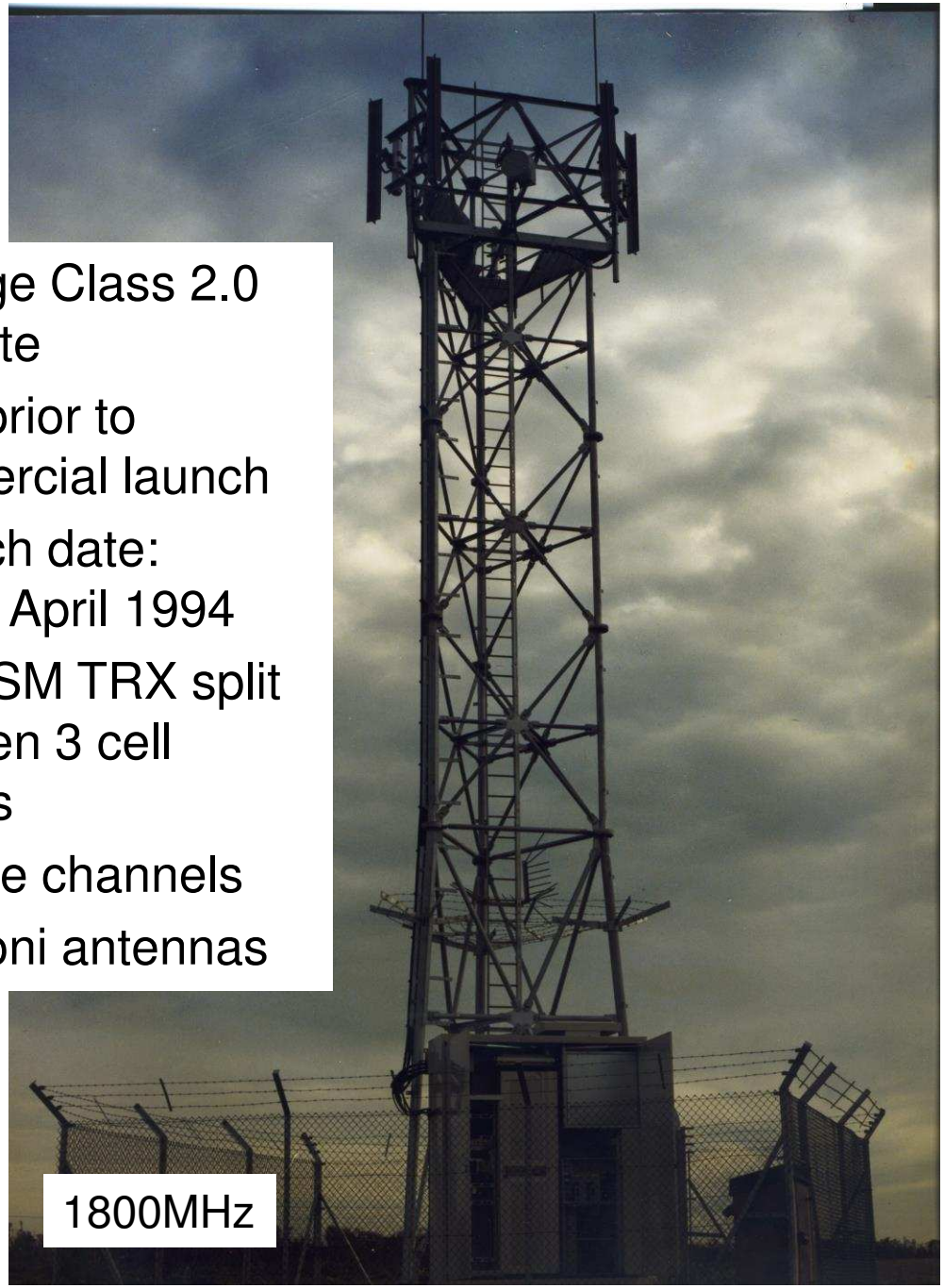


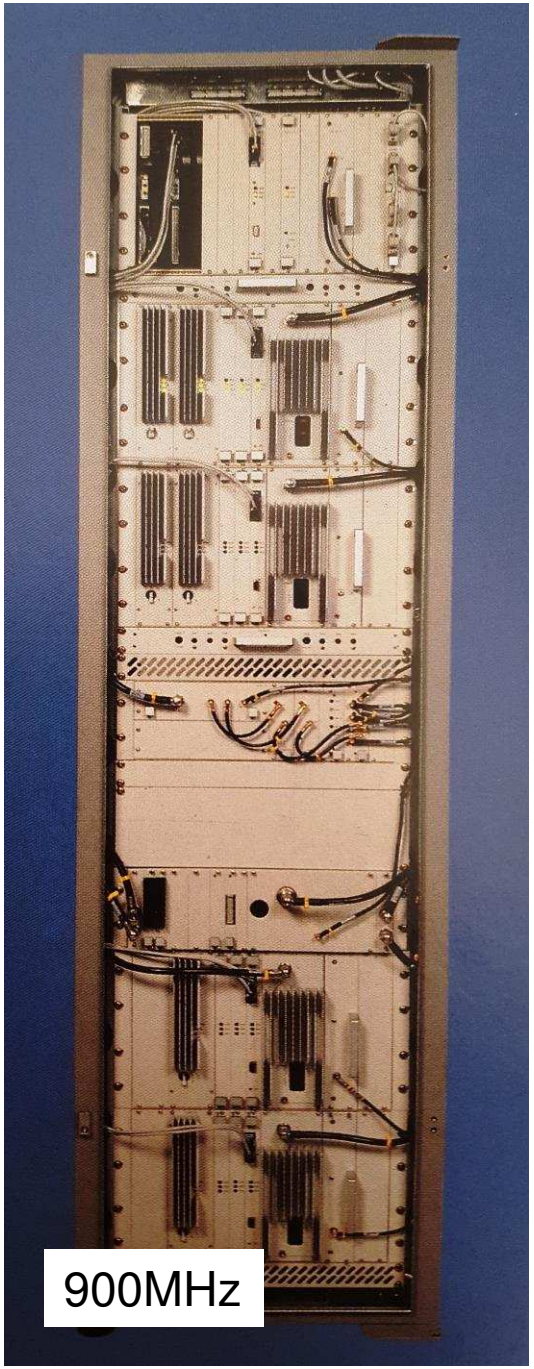
GSM network architecture



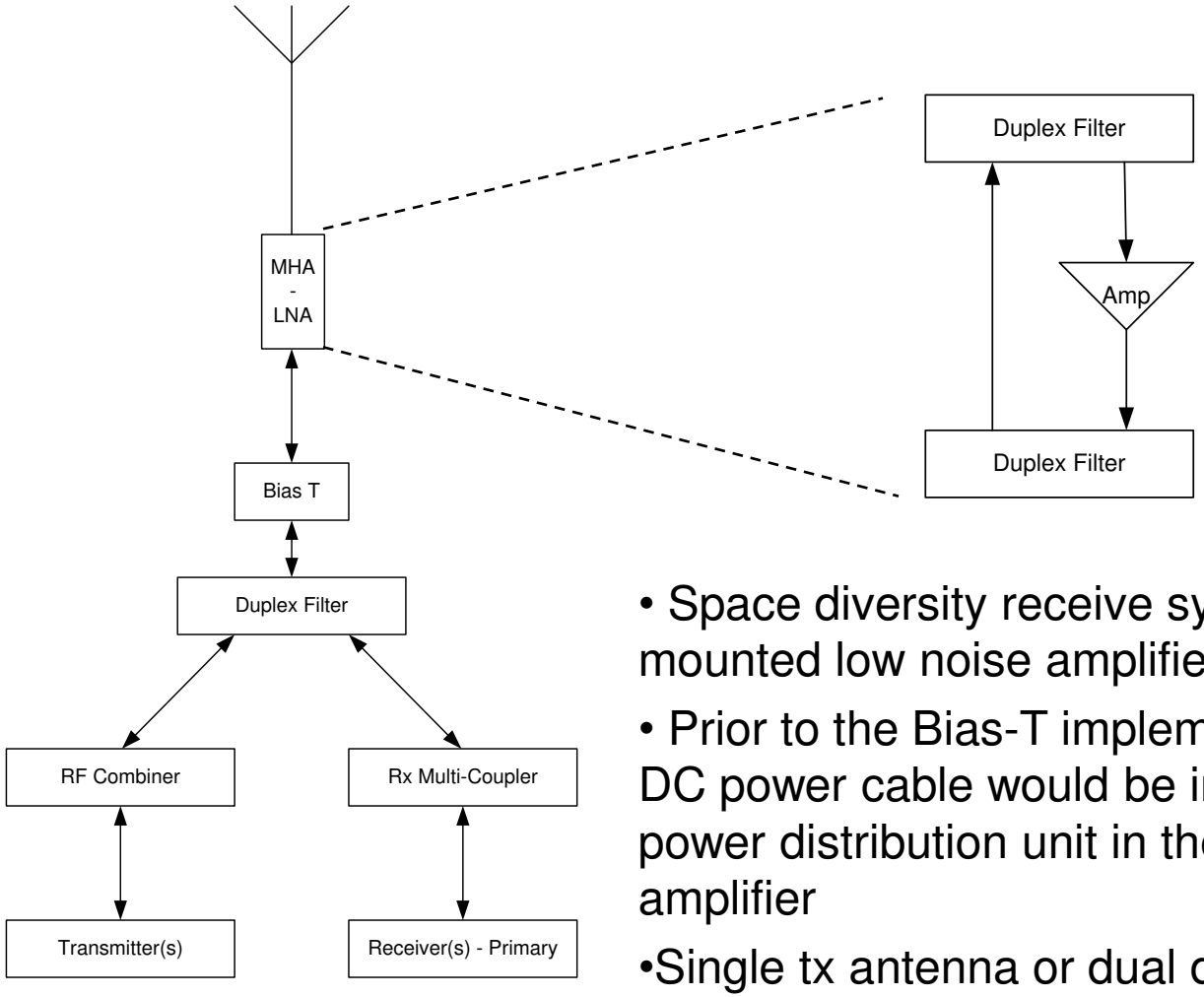
GSM

- Orange Class 2.0 BTS site
- Built prior to commercial launch
- Launch date: 28 April 1994
- 1 x GSM TRX split between 3 cell sectors
- 7 voice channels
- Marconi antennas



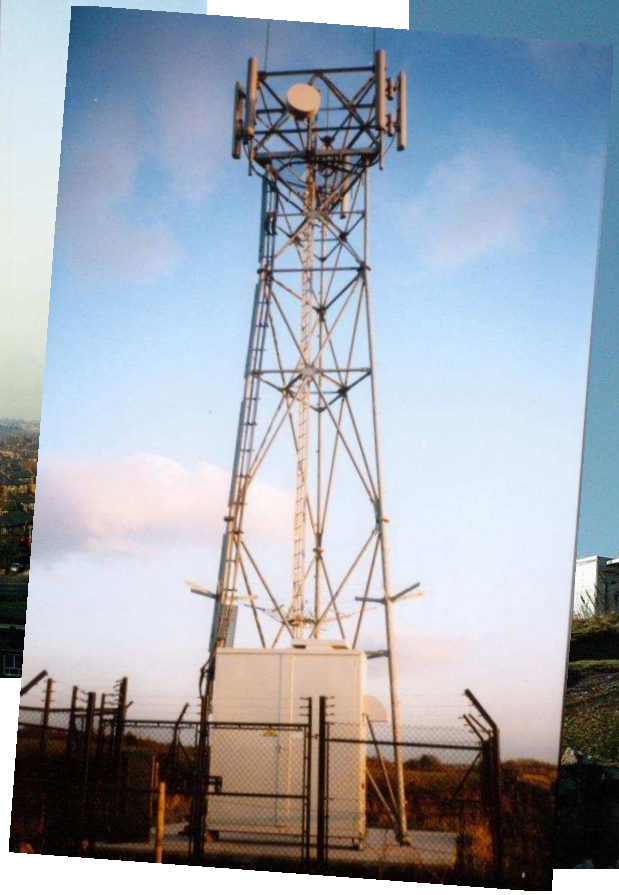


Antenna systems



- Space diversity receive systems and tower mounted low noise amplifiers improve the uplink
- Prior to the Bias-T implementation, a separate DC power cable would be installed between a power distribution unit in the cabin and each amplifier
- Single tx antenna or dual duplex configuration

GSM cell sites & line of sight microwave radio hubs



External GSM BTS cabinets

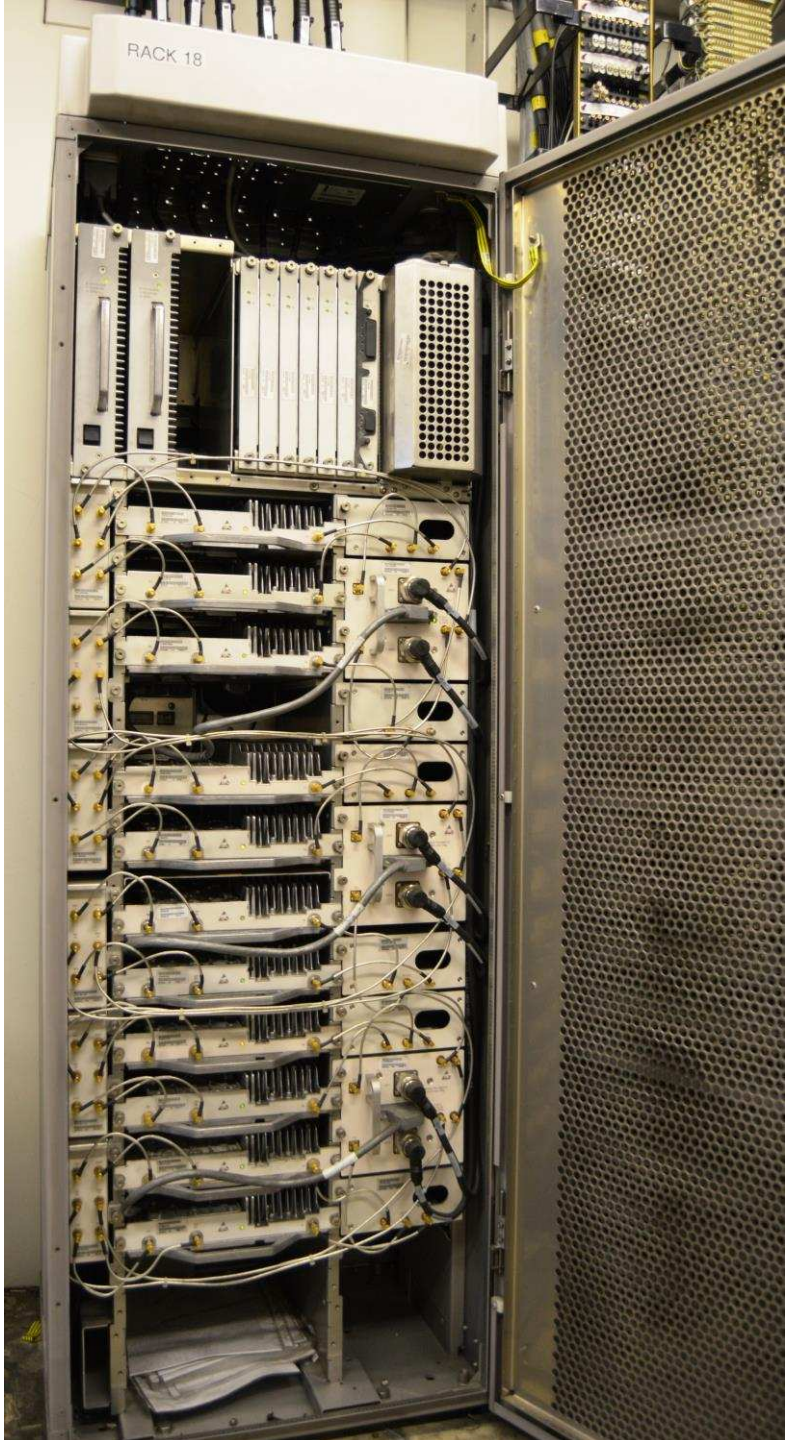
Ericsson 2000 series RBS

Nokia DF-34 (Talk Family) BTS

GSM micro-cells

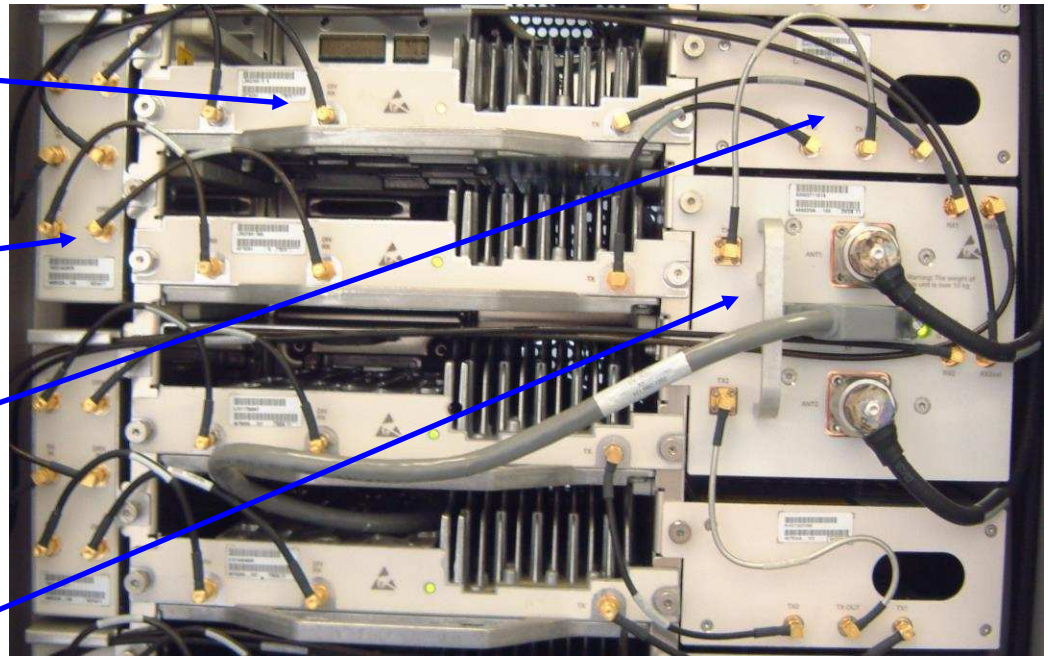
GSM BTS evolving to high-cap

- Nokia Ultrasite GSM BTS
- Up to 12 x GSM TRX in a single rack
- Can be extended to multiple rack
- Maximum of 6 x GSM TRX per cell sector
- Typically 3 cell sectors per site however 4, 5 and 6 cell sectors are deployed as required
- Single 2.048Mbps (E1) Abis interface per rack
- Abis interface supports TRX signalling, traffic and Operations & Maintenance channels
- Abis interface connects BTS to BSC



4 x GSM transceivers in one cell sector

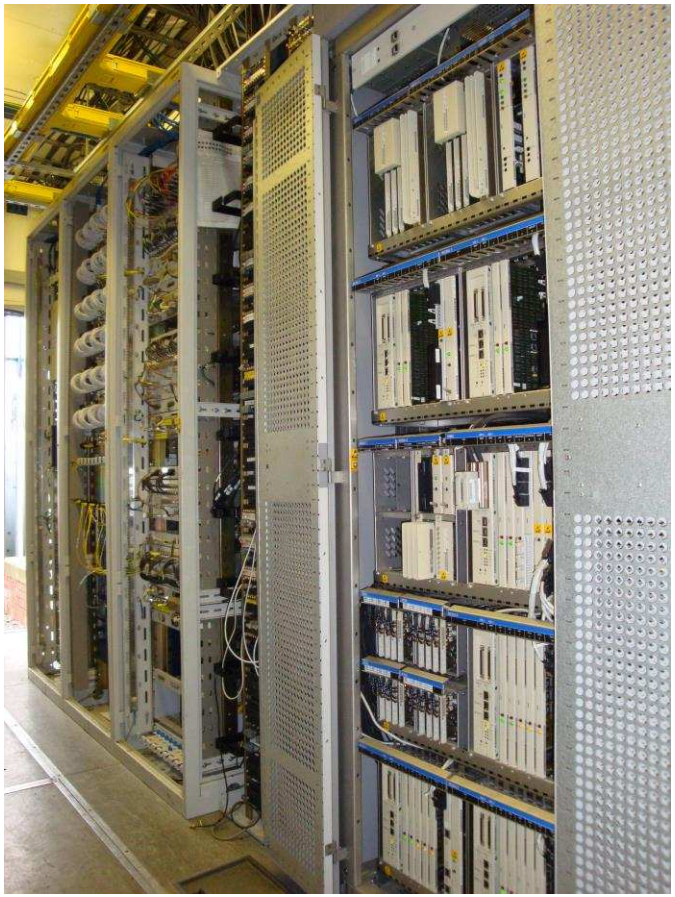
- TRX
- Rx multi-coupler
- Tx combiner
- Duplex filter



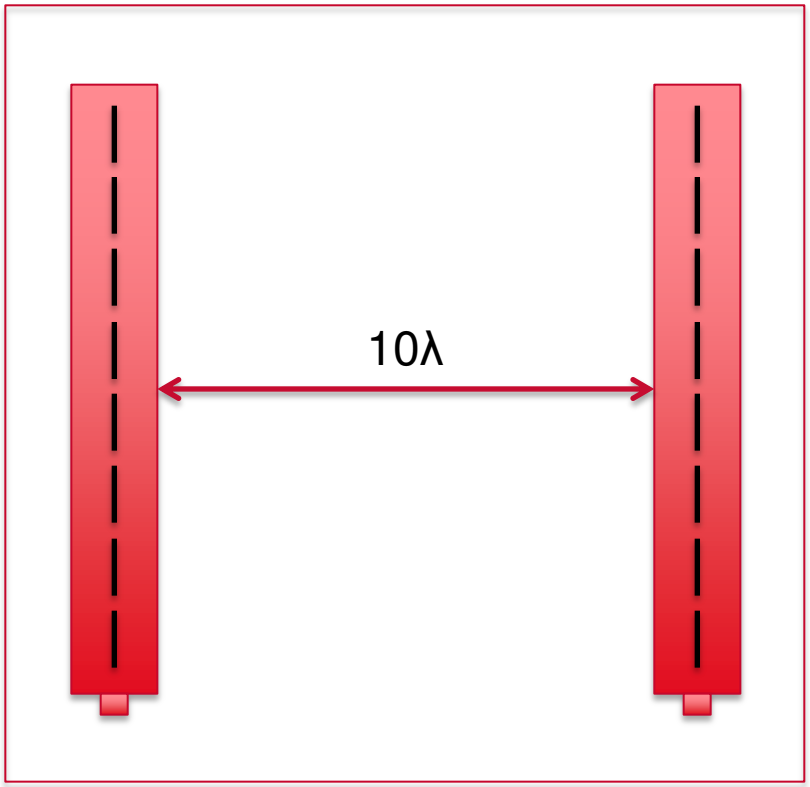
GSM/GPRS network architecture

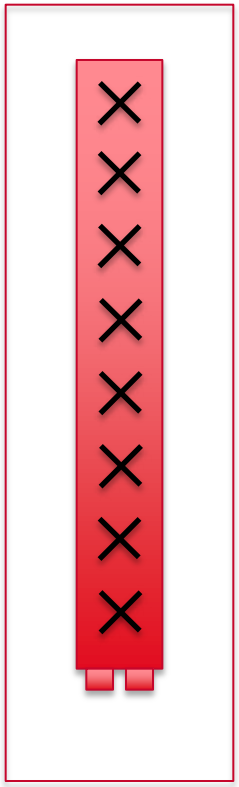
BTS
BTS
BTS
BTS
BTS
BTS
BSC/
PCU
BSC/
PCU
TRAU
MSC
PSTN
Databases
GPRS
SGSN
GGSN
Data
Networks
Access Network
Circuit Switched
Packet Switched

4 cell sector GSM BTS and BSC

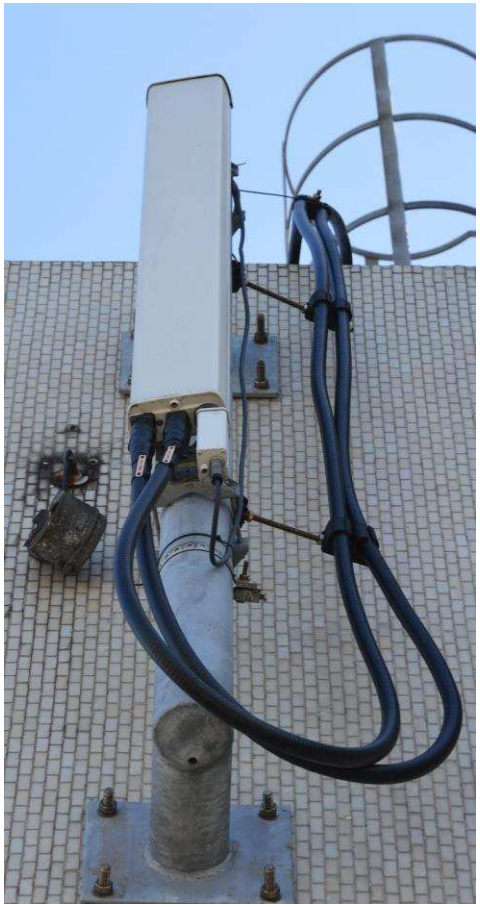


From space diversity to polarisation diversity





Space diversity and polarisation diversity antennas



Structures and antenna systems

Dual band single polarisation
(space diversity)

Dual band cross polarisation
(polarisation diversity)

Dual band cross polarisation
(polarisation diversity)

Single band cross polarisation
(polarisation diversity)

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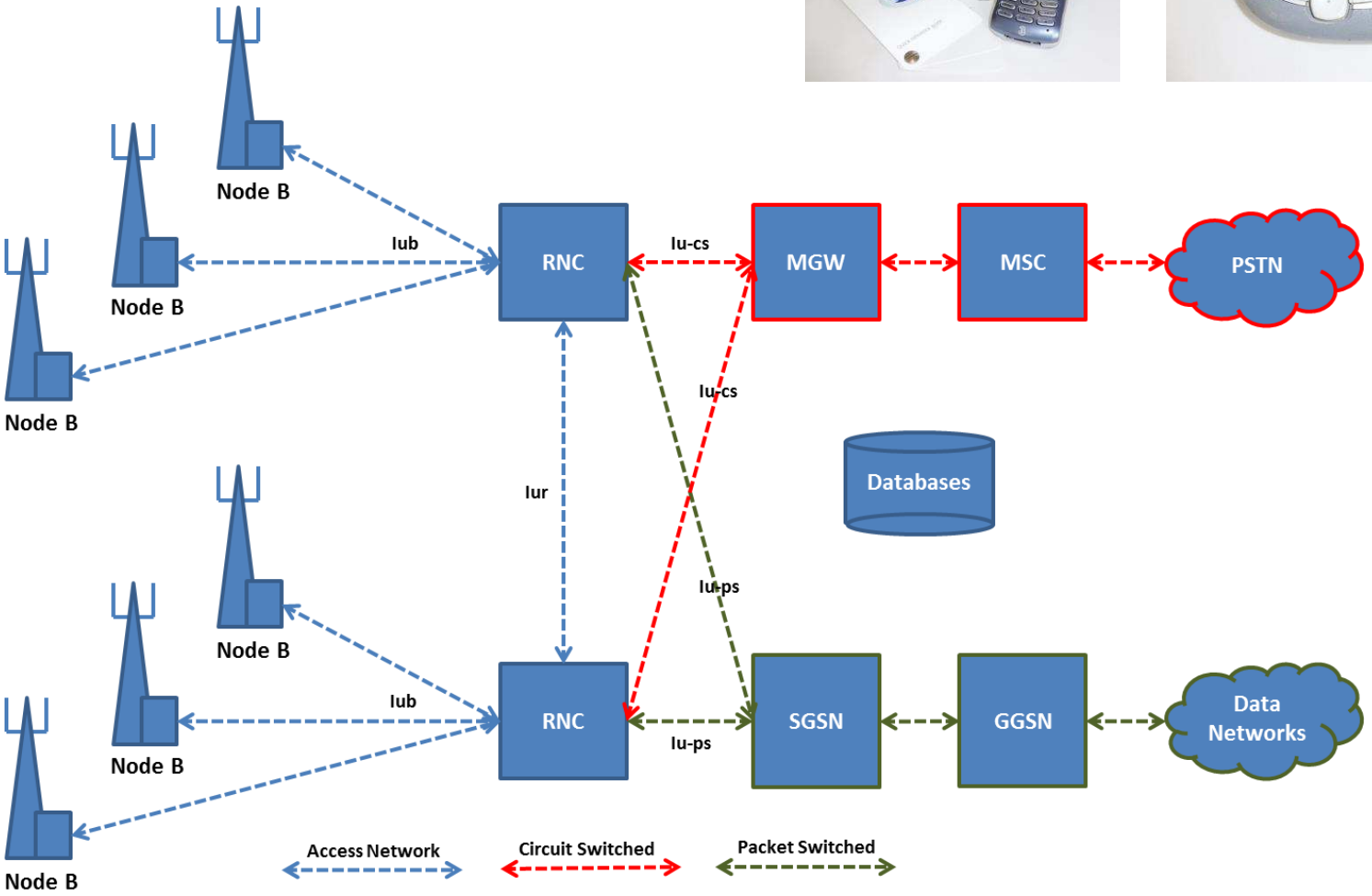
ADDING UMTS (3G)

UMTS (3G) - An expensive auction…

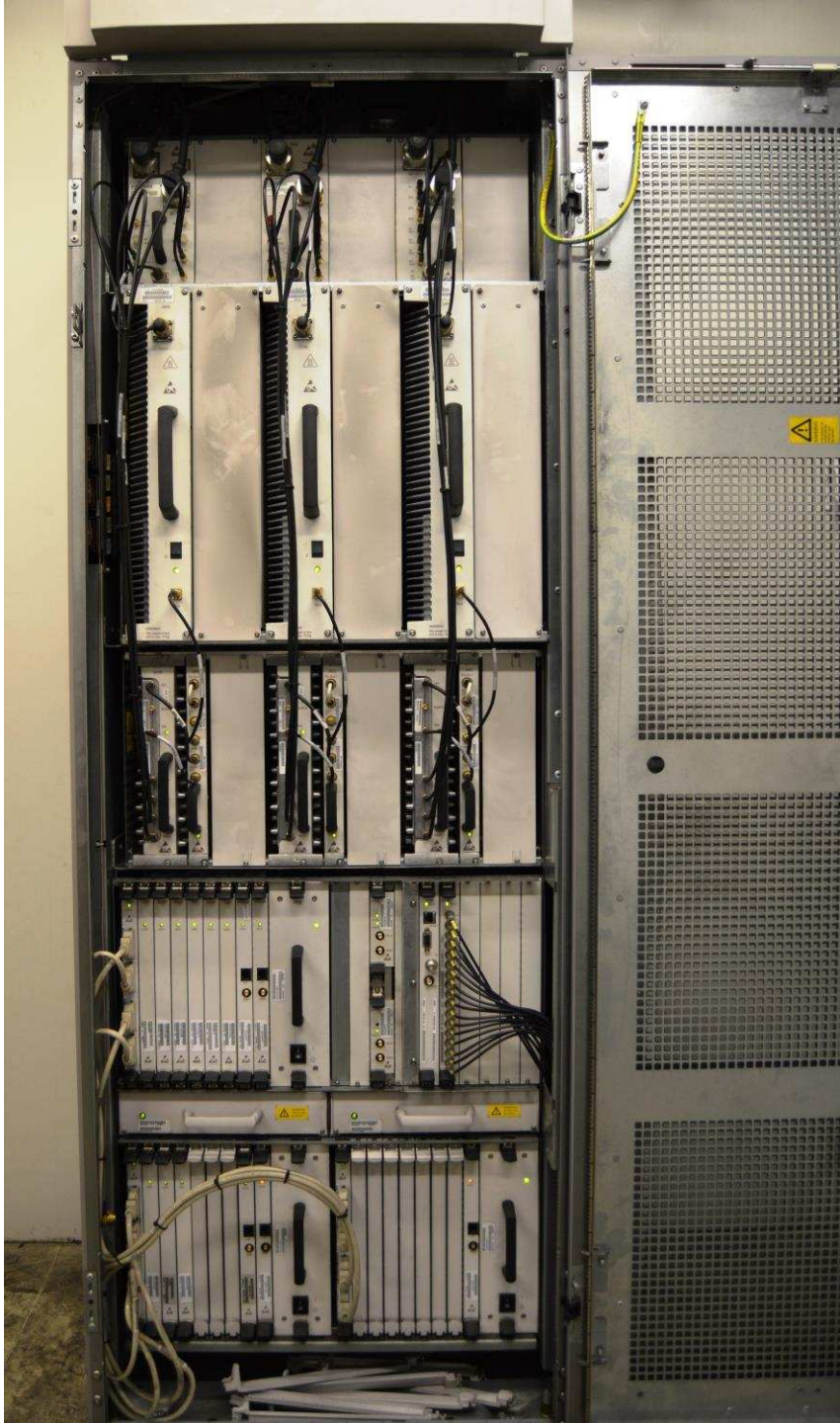
- Now let' start again with 3G @ 2100MHz…
- Licence A: TIW at a cost of £4,384,700,000
- Licence B: Vodafone at a cost of £5,964,000,000
- Licence C: BT at a cost of £4,030,100,000
- Licence D: One2One at a cost of £4,003,600,000
- Licence E: Orange at a cost of £4,095,000,000

UMTS network architecture



UMTS NodeB

- Nokia Ultrasite UMTS NodeB
- WCDMA BTS
- Configured with 2 x 5MHz FDD carriers per cell sector
- Up to 8 x 2.048Mbps (E1) interfaces for IMA per NodeB
- Large class A power amplifiers



3G infill sites – O2 & Vodafone

adding 2100MHz to an established 900MHz site grid

Ericsson RBS 3107 cabinet

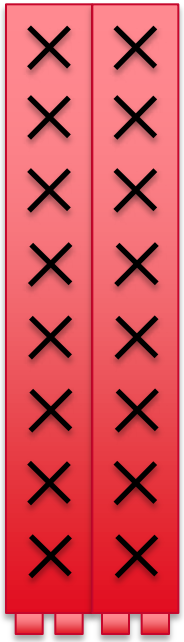
Network sharing

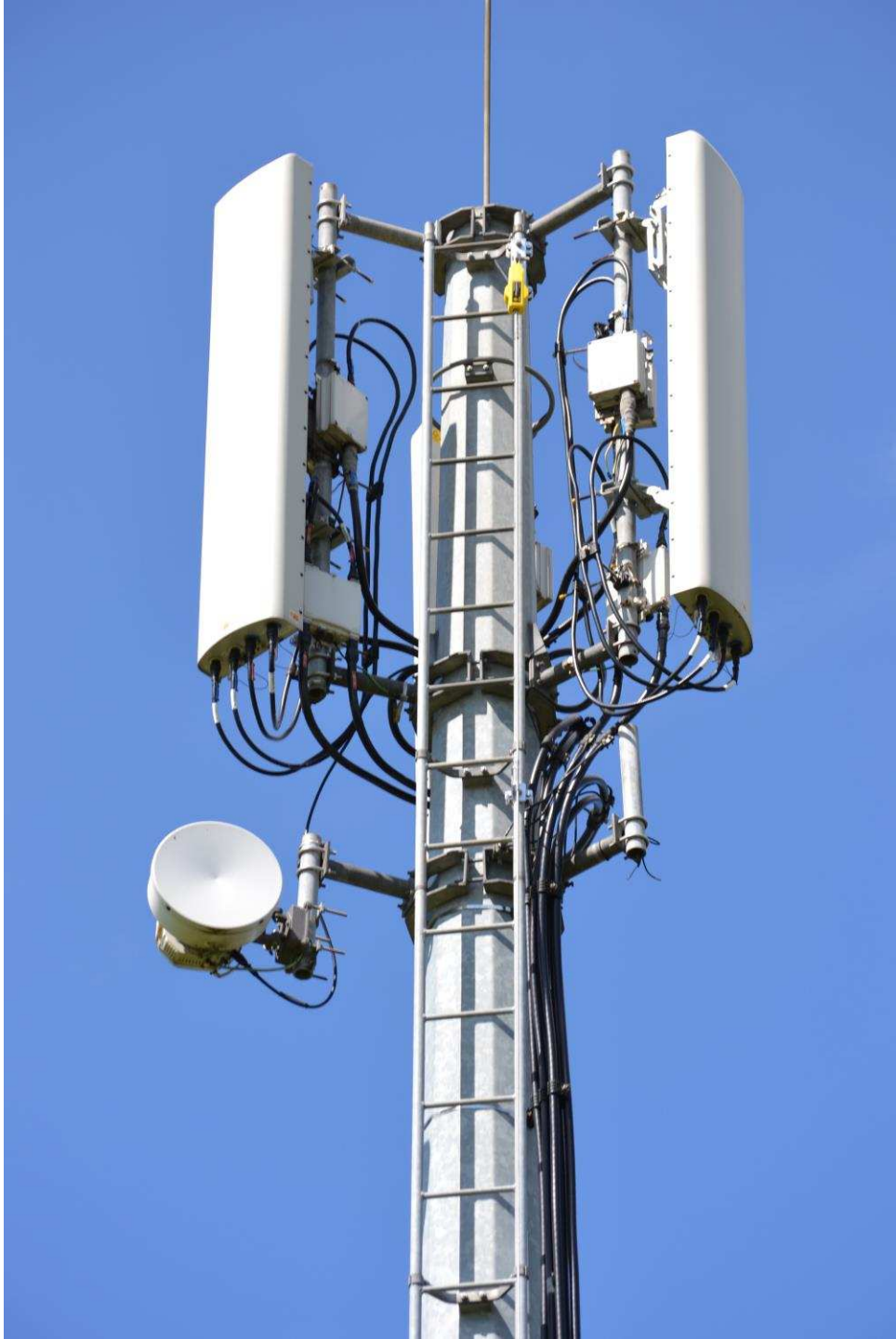
- MBNL - Mobile Broadband Network Limited
  - Originally formed in 2008 as a joint venture between H3G and T-Mobile
  - Delivered 3G MORAN along with support for T-Mobile's 2G network
  - Orange and T-Mobile merged in 2010 to form Everything Everywhere
  - MBNL then owned by H3G and Everything Everywhere
  - MBNL supports Orange/T-Mobile integration programme
  - Everything Everywhere changes its name to EE and launches the UK's first mobile 4G (LTE) network - on the MBNL shared network grid
  - H3G deploys 4G LTE on the MBNL shared network grid
  - EE is acquired by BT and becomes part of BT Group
- CTIL - Cornerstone Telecommunications Infrastructure Limited
  - Formed in 2012 by Vodafone and Telefonica (O2)
  - Delivering a single shared network grid
  - Project Beacon delivers a shared network infrastructure using dedicated spectrum
  - Vodafone is in charge of the network maintenance in the West of the UK and Wales, while O2 will be looking after the East, including Northern Ireland.

Nokia Flexi 2.0 WCDMA BTS (UMTS NodeB)

Antenna system

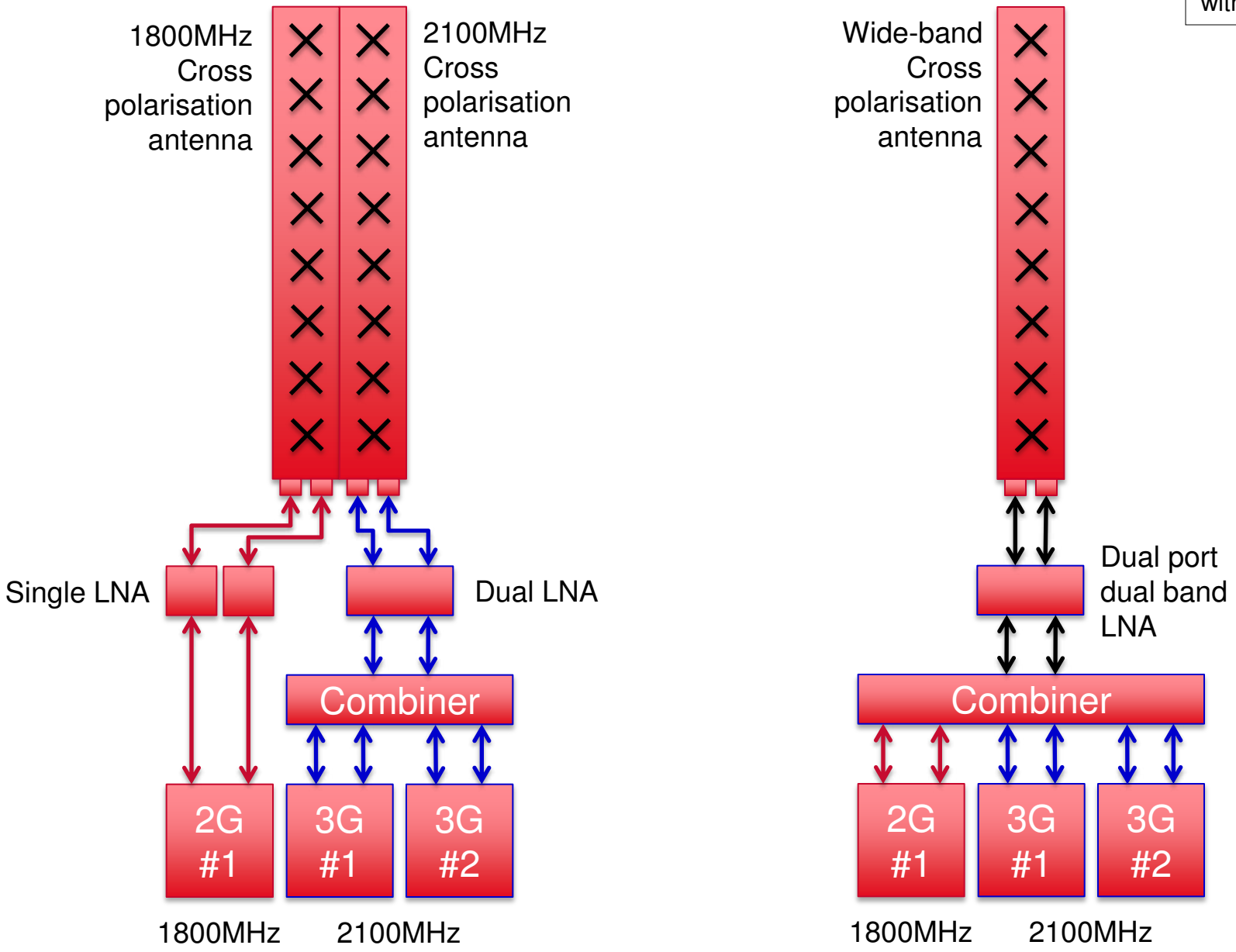
- Dual band cross polarisation antennas
- 1800MHz
- 2100MHz
- Single port LNAs for UMTS 2100
- Dual port LNAs for GSM 1800
- 4 Coaxial feeder cables per cell sector
- Microwave radio for backhaul connection





Example site configurations for shared 2G/3G site

#1 – MNO with 2G & 3G
#2 – MNO with 3G only



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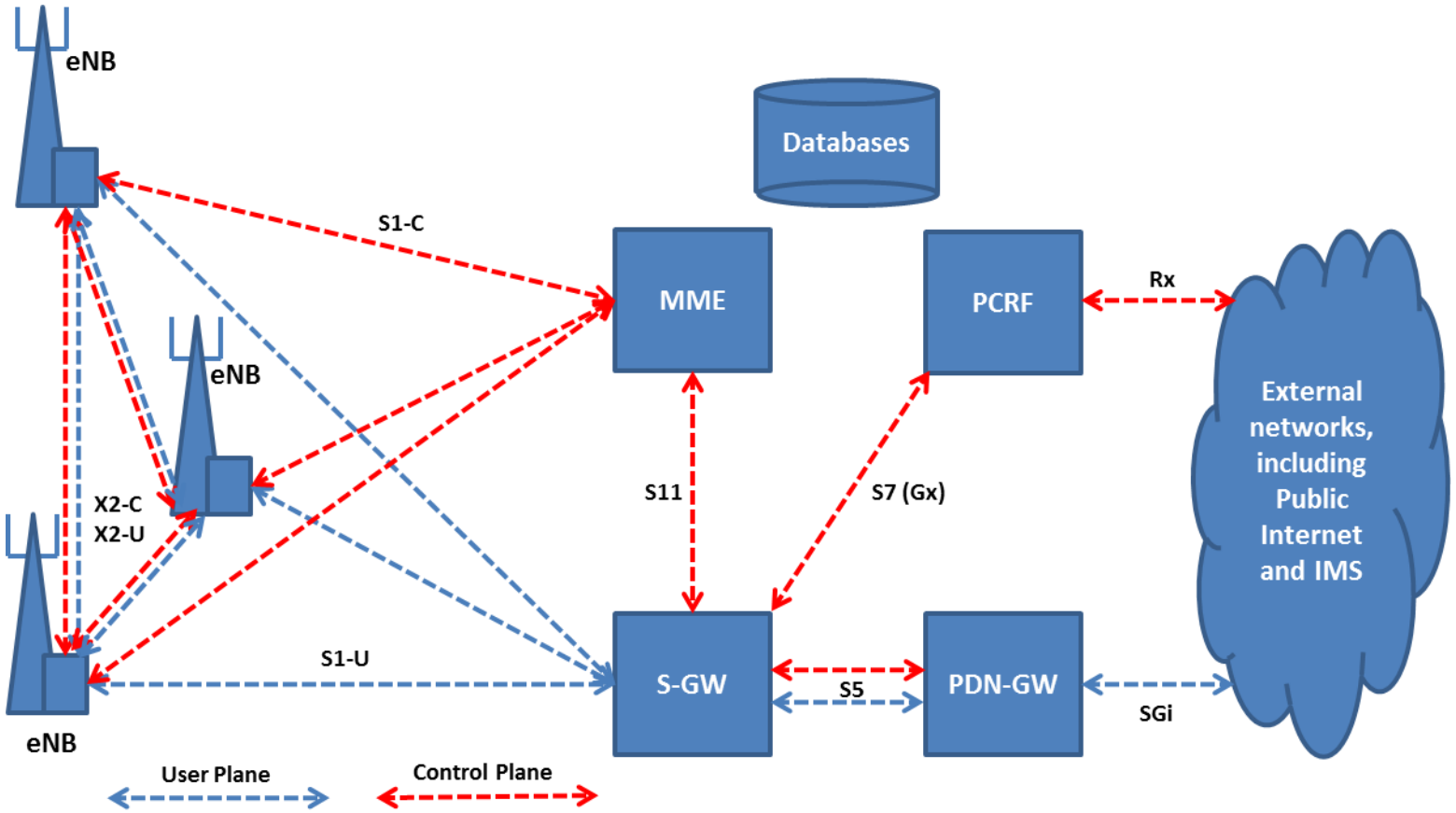
ADDING LTE (4G)

LTE network architecture



4G and spectrum re-farming

Ofcom allows Everything Everywhere to use existing spectrum for 4G

21 August 2012

Ofcom has today approved an application by the mobile phone operator Everything Everywhere (EE) to use its existing 1800 MHz spectrum to deliver 4G services.[1]

Following a consultation, Ofcom has concluded that varying EE's 1800 MHz licences now will deliver significant benefits to consumers, and that there is no material risk that those benefits will be outweighed by a distortion of competition.[2] Delaying doing so would therefore be to the detriment of consumers.

The decision takes account of the forthcoming release of additional spectrum in the 800 MHz and 2.6 GHz bands, in an auction process set to begin later this year, which will enable other operators to launch competing 4G services from next year.[3]

In parallel with this decision, Ofcom has now issued varied licences to EE which authorise LTE services from 11 September 2012. This means that EE can launch LTE services using its 1800 MHz spectrum at any point from that date, although the precise timing of any launch is a commercial decision for Everything Everywhere.

The full decision can be found here.

ENDS

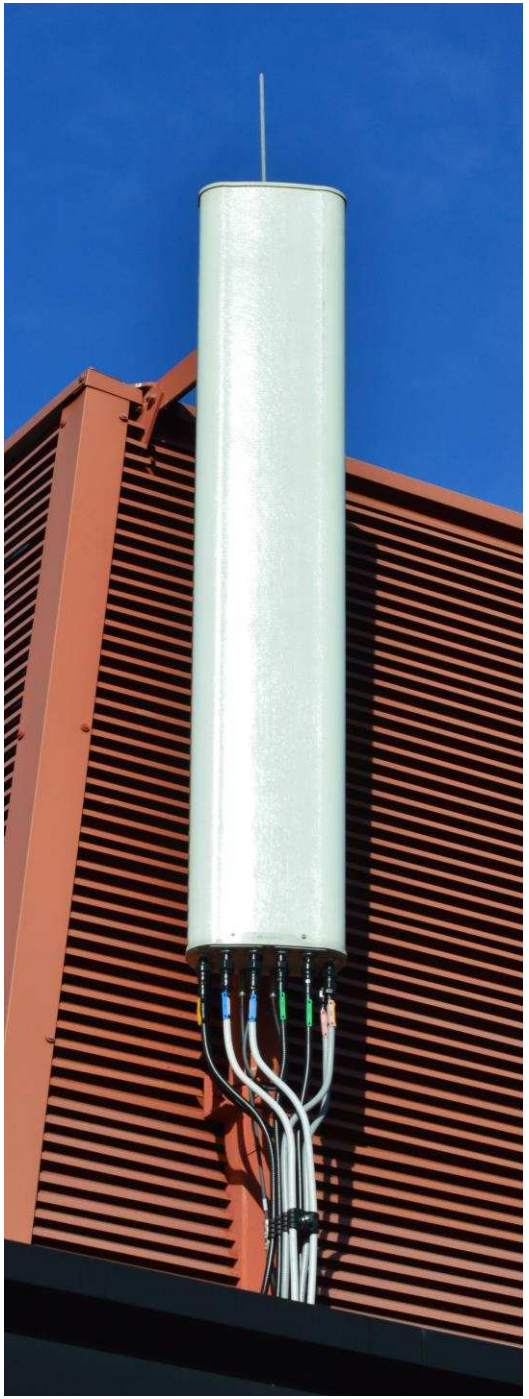
Source: https://www.ofcom.org.uk/about-ofcom/latest/media/media-releases/2012/ofcom-allows-everything-everywhere-to-use-existing-spectrum-for-4g

Another spectrum auction

Company	Spectrum	Price
Everything Everywhere (EE)	2x5MHz in the 800MHz band plus 2x35MHz in the 2600MHz band	£588,876,000
Hutchison 3G Limited (3)	2x5MHz in the 800MHz band	£225,000,000
Niche Spectrum Ventures Limited (BT):	2x15MHz and 1x25MHz in the 2600MHz band	£201,537,179
Telefonica UK Limited (O2):	2x10MHz in the 800MHz band	£550,000,000
Vodafone Limited	2x10MHz in the 800MHz band plus 2x20MHz and 1x25MHz in the 2600MHz band	£802,860,143

The 2x and 1x refers to FDD and TDD operation

4G network rollout
eNBs, RRUs and new antennas



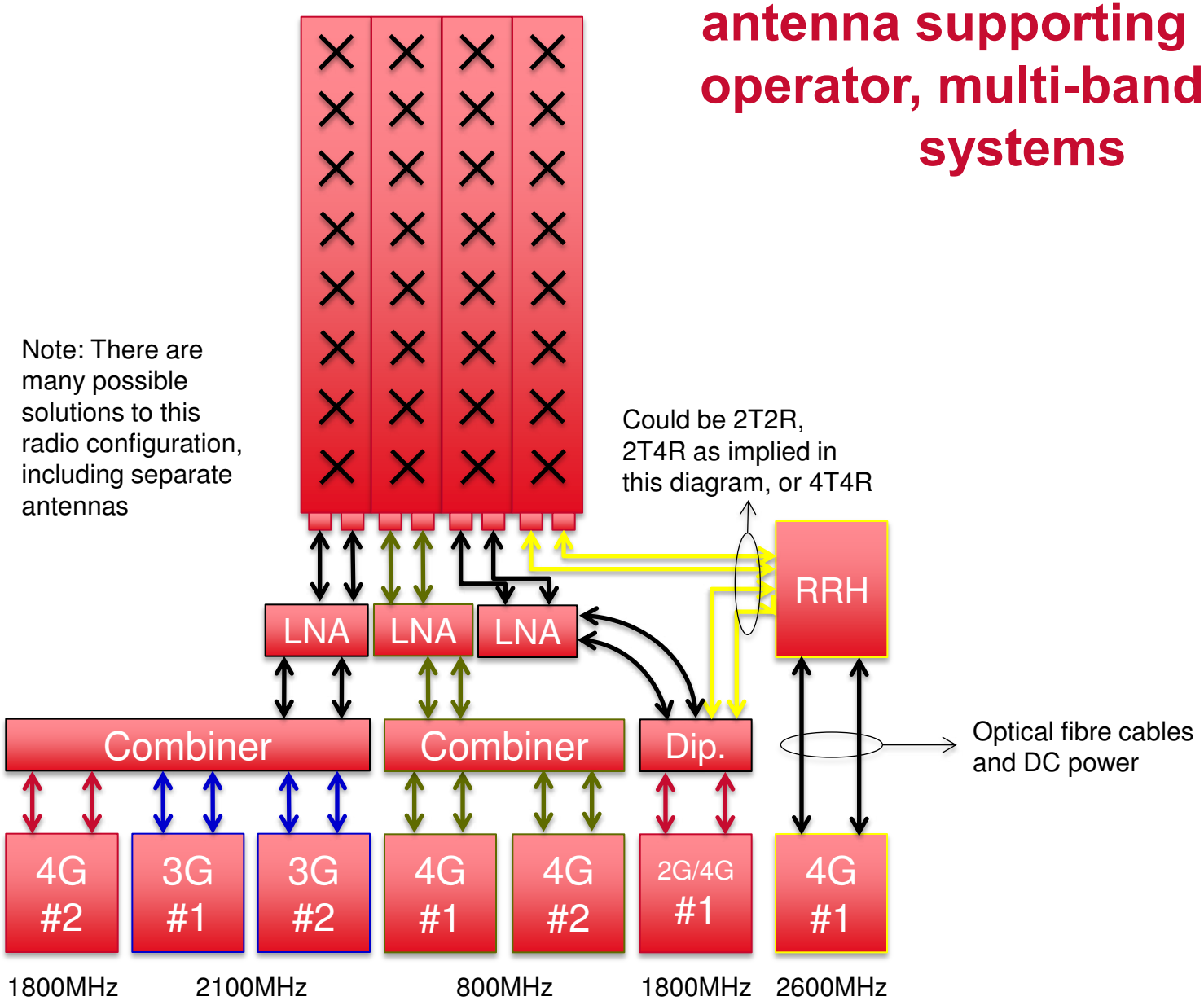
New frequency bands and a new radio access technology

- 4G is based on LTE
- The radio interface is OFDMA in the downlink and SC-FDMA in the uplink
- MIMO (multiple input / multiple output) antennas system is introduced
- All mobile bands are now technology neutral and as such can be used for 4G
- Extremes of cellular frequency usage extended from:
  - 900MHz - 2100MHz to
  - 800MHz - 2600MHz
  - (even higher bands to come)

New site design options - Remote radio Units (RRU)

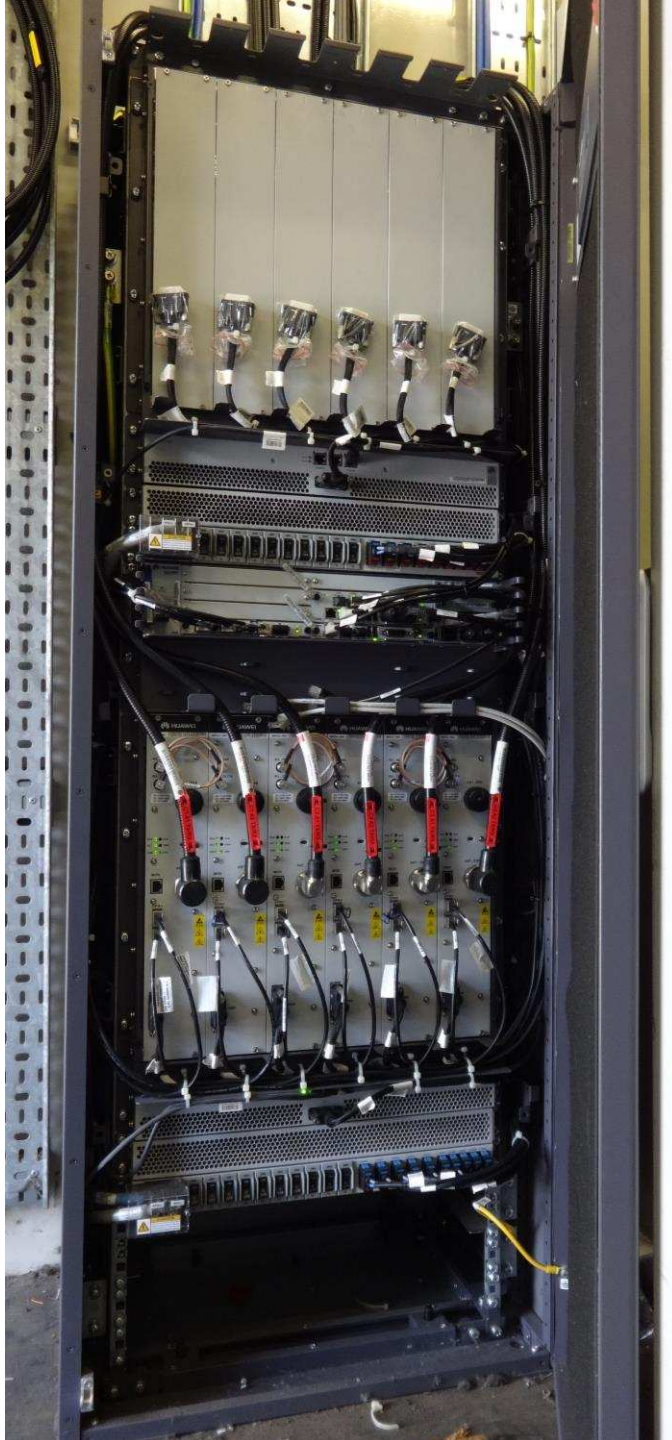
- Traditional cellular base stations have accommodated all radio equipment (with the exception of TMAs) in a cabinet at ground (or roof top) level
- New radio base stations support RRUs for many bands, particularly the higher frequency bands - given increased loss through coaxial feeder cables
- RRUs improve the downlink and uplink link budget
- However, they're not practical on all structures and present certain operational challenges
- In many cases, low bands are still cabin based while higher bands may make use of RRUs.

An example of an 8 port antenna supporting multi-operator, multi-band radio systems



LTE eNB

- Huawei 3900A multi-RAT, multi-band base station
- Configuration shown supports GSM and LTE in the 1800MHz band
- Available as indoor and outdoor variants
- Outdoor variant may be stacked or side by side
- Different variants in use by different operators



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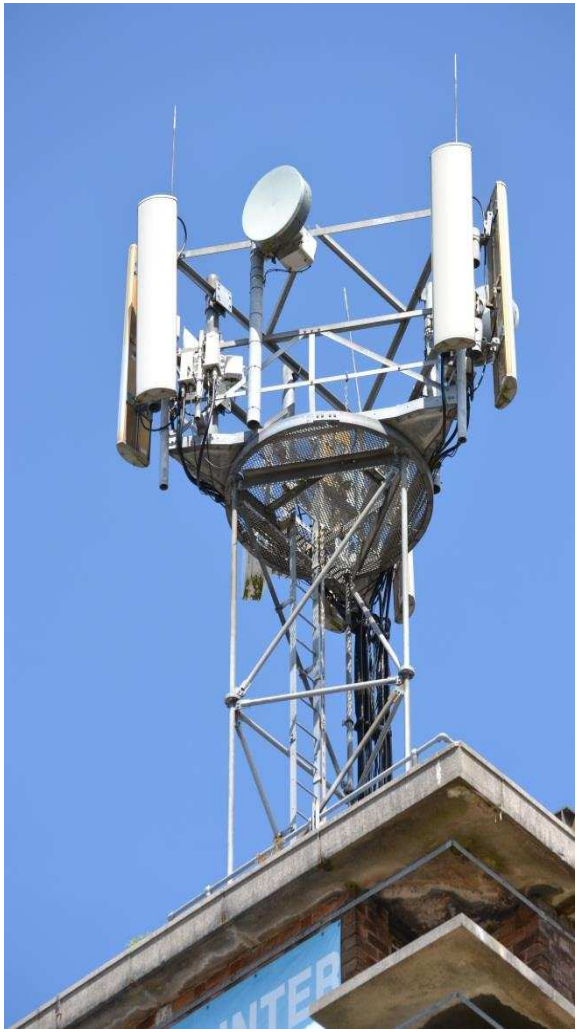
TYPOLOGY OF CELLULAR RADIO SITES

Traditional cellular towers

Rooftops

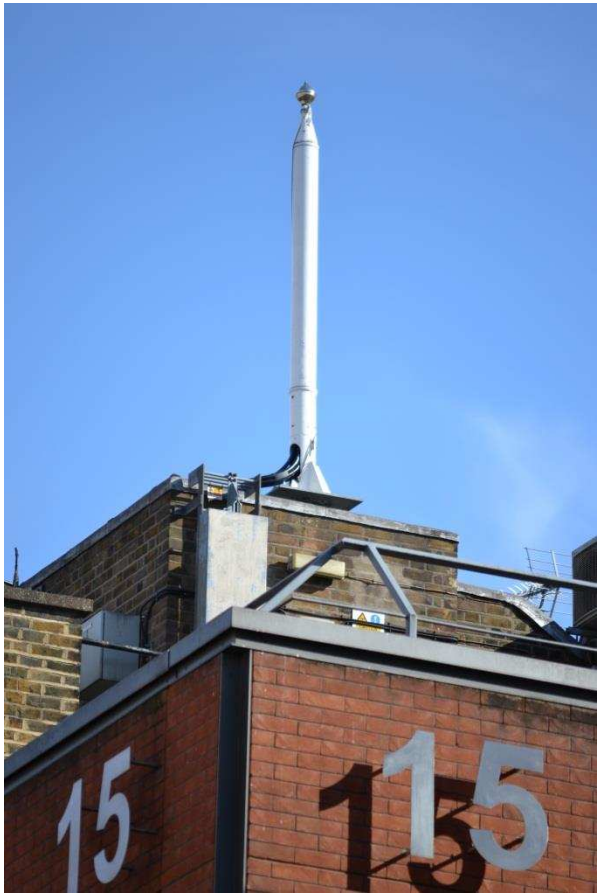


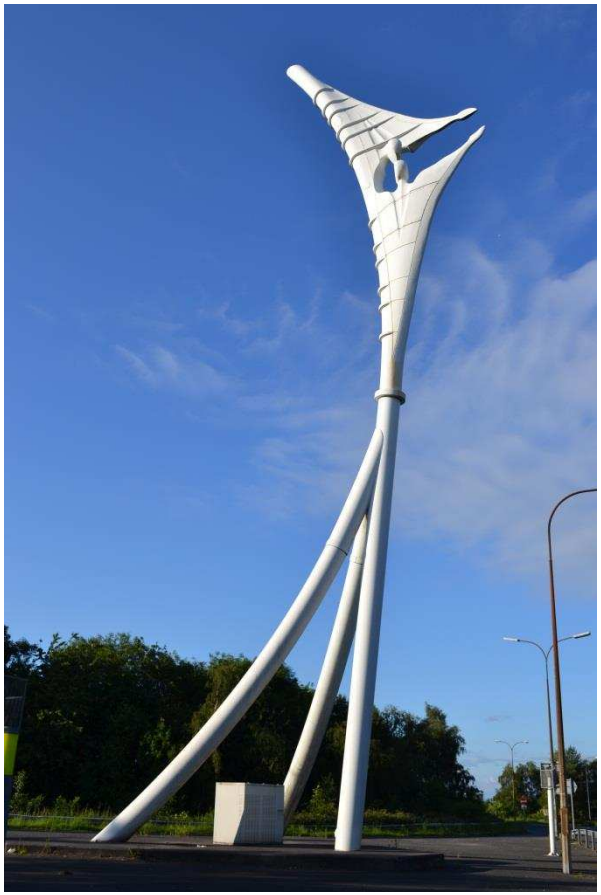
Macro columns

Streetworks

Something a little different…

and more…





and yet more…

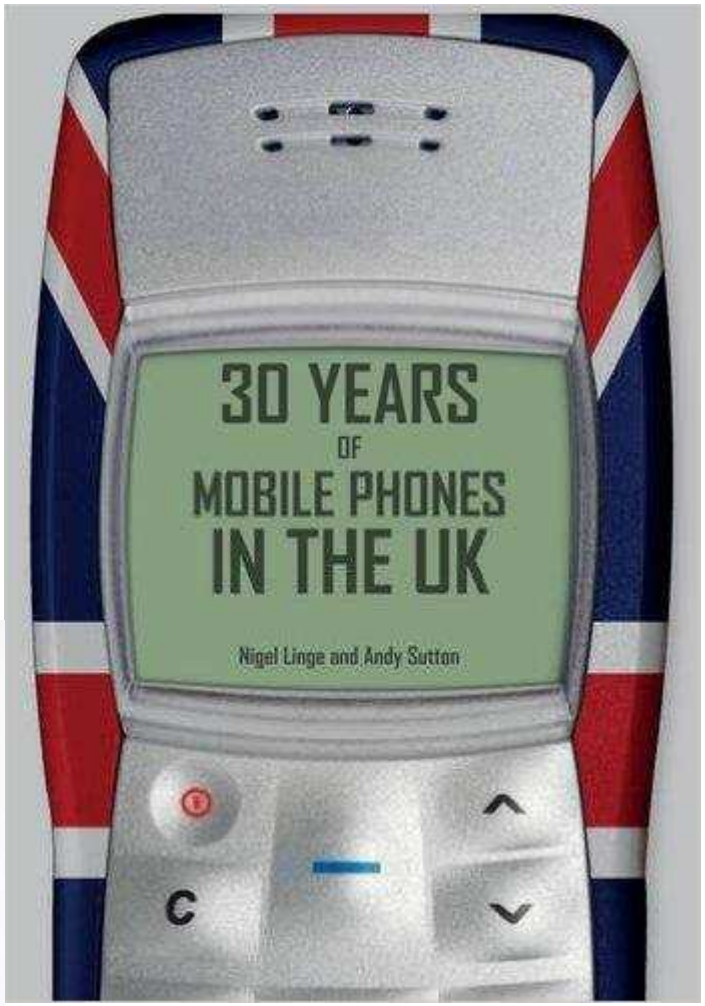
Micro-cells

Summary

- In just over 30 years the UKs cellular mobile communications networks have evolved from supporting basic analogue voice telephony to high speed multi-media communications
- The networks are constantly evolving to meet ever growing demands for coverage, capacity and performance
- The last 30 years has witnessed four generations of mobile communications technology, and 5G is on its way!
- The history and heritage of mobile communications is poorly documented, this research is an attempt to address this concern…

30 years of mobile phones in the UK

- Published in 2015
- Amberley Publishing
- 15,000 words (96 pages)
- 111 photographs
- Tells the story of 30 years of mobile phones in the UK through the evolution of handsets



Further reading

- NEW BOOK: 30 Years of Mobile Phones in the UK: https://www.amberley-books.com/30-years-of-mobile-phones-in-the-uk.html - available from Amazon and all good book retailers
- IET TV: End to end and top to bottom network design: https://tv.theiet.org/?videoid=7664
- 5G - The Future of Mobile Communications - ITP Journal paper: https://www.academia.edu/11743695/5G_-_The_Future_of_Mobile_Communications
- Microwave and millimetre wave radio systems - ITP Journal paper: https://www.academia.edu/13885538/Microwave_and_Millimetre_Wave_Radio_Systems
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